

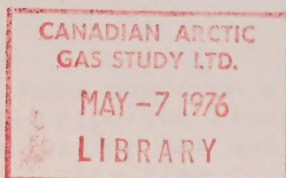
WATER QUALITY CRITERIA FOR PROTECTION OF AQUATIC LIFE

Presentation to
the Mackenzie Valley Pipeline Inquiry.

MACKENZIE VALLEY PIPELINE INQUIRY
EXHIBIT TO J-15 Mar. 25/76
Yellowknife, N.W.T.
Canadian
Arctic Gas.

by

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Yellowknife, March 1976.

REACTION TO BACKGROUND STUDIES AND REPORTS

I am very much impressed by the baseline and impact studies carried out by Arctic Gas* and the government. The work on fish and other aquatic life is of high quality and provides a wealth of new knowledge. These large and expensive studies speak highly about the intentions of all concerned, to avoid any serious environmental degradation. Indeed it is a pleasure to see such large numbers of powerful scientists involved in environmental impact studies. It is an enormous improvement over the situation in the 1950's, when one could count the active "pollution biologists" in Canada on the fingers of one hand. My further remarks on improved procedures for protecting aquatic life should be taken in a context of general approval for the excellent background provided so far.

With two reports -- those of the government Pipeline Application Assessment Group, and the 4-volume report of the Environment Protection Board, I am particularly impressed, and in almost total agreement. These are highly perceptive and contain excellent detailed proposals.

I recommend that the decisions arising from this hearing should incorporate the concrete suggestions on fisheries and water quality put forward in both of these reports.

In particular, I agree with the EPB report (volume 1, p. 41) that the applicant shows awareness, but "has not transferred this awareness into environmental specifications" and did not include such detailed specifications. My major impressions in reading the application and background reports are (1) the vast amount of information in the baseline studies, and (2) the absence of specific numerical standards for water quality, together with lack of exact specifications for tolerable construction practices. The emphasis in the application is to "minimize" or "avoid" environmental effects, without saying exactly how this would be done, or exactly what water quality standards would be maintained.

I therefore recommend that specific regulations be developed, along the lines proposed by EPB, especially in their "Environmental Code" (volume 2).

* This evidence has been based on a review of documents by Canadian Arctic Gas Pipeline Limited. The Foothills Pipe Lines Limited application has not been reviewed sufficiently to make comments at this time.



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GENERAL OPINIONS ARISING FROM EXPERIENCE

Based on my overall experience, I have some feelings about water quality criteria for protection of aquatic life, and how these criteria should be implemented to avoid environmental damage. Applied to Mackenzie valley pipeline construction, I must say that I am particularly wary of the side-effects of construction activities.

In my experience, the people on a construction project usually have their hands full, dealing with the everyday problems and crises of getting their job done. Seldom do they have the leisure for day-to-day consideration of environmental side-effects. I have seen this in mining and forestry activities, and in road construction.

The last item is perhaps the most relevant. I was closely involved in detailed planning and study of an expressway crossing of a small trout-stream in Guelph. There happened to be a waterfowl sanctuary downstream. A team of engineers, environmentalists, and planners was assembled to advise the city and the Ontario Ministry of Transportation how to make the crossing and to develop the watershed later, with minimal damage to the natural habitats. Specifications were produced for settling ponds to catch construction silt, for minimal cutting of trees, for sodding (not seeding) of road embankments, and general construction practice. The study cost about \$30,000 although professional time was donated, and produced about three inches of reports, rather a lot for a small watershed in southern Ontario.

Yet what my student and I saw on the day-to-day operations was rather different than recommended. Bulldozer operators casually drove across the stream instead of going 40 yards more to cross by the road. It took repeated complaints to stop this. Replanting didn't get done in time and embankments eroded. Settling ponds did not get cleaned out. An extensive construction yard became churned up with mud, and once provided an oil spill from unknown source. Rechannelization of the stream through the culvert caused a massive surge of siltation, severely reduced resident fish populations in a downstream section. Suspended solids reached a peak of 1400 mg/litre. At one point, the city engineer produced plans for a sewer line down the creek. Finally, a two-year follow-up noted unexpected downstream changes -- evidence of gradually increasing enrichment of the stream and changes in fish populations. These were apparently typical "urbanization" changes, from relatively minor activity on the watershed.

All this happened in southern Ontario, which is noted among other things for its lack of permafrost problems, and its mild climate. Such experiences have convinced me that there should be detailed regulations for construction activities, spelling out water quality standards and construction practices, and that there should be an inspection system for compliance.

WATER QUALITY CRITERIA BACKGROUND

Water quality criterion: A scientific requirement of quality needed for a certain use of water—in this case for a certain level of environmental preservation.

The general approach and philosophy behind water quality criteria is given by this definition. For protection of aquatic organisms from any given pollutant, a numerical value is decided upon, which will provide protection, based on the best available scientific knowledge. For the same pollutant, criteria may be quite different for other uses of the water. For example, aquatic organisms may be harmed or even killed outright by concentrations of copper or chlorine which are 10, 100, or 1,000 times lower than the safe concentration for human drinking water.

Criteria for aquatic organisms can only be determined by scientific investigation. Today, much of this takes place in the laboratory, by studying the lethal and sublethal effects of a given pollutant on selected animals and plants. A good example would be studying the survival, growth, and reproduction of groups of fish which are continuously exposed to a series of constant concentrations of the pollutant, through an entire life-cycle, from newly-hatched fry, through to the next generation of young fish. Other experiments on the same pollutant might perhaps involve similar studies on an invertebrate animal or alga, or avoidance reactions of fish to the pollutant, or accumulation of the pollutant through the food-chain to predatory animals such as birds.

From such experiments, scientists estimate what concentrations are harmful to aquatic organisms, and the concentrations which are "safe".

The laboratory experiments should ideally be confirmed by experimental studies in natural habitats. These tend to be more costly and difficult to control, and accordingly such projects are fewer. However, those field studies which have been done, usually confirm closely the predictive capabilities of the laboratory tests. In one of the best field tests, a natural stream in Ohio was dosed with copper (Brungs *et al.*, 1976). It confirmed the laboratory estimate of the criterion for permitting reproduction of fish, and showed that the copper criterion for avoidance reactions of fish was somewhat lower.

The most comprehensive compendium of water quality criteria to date is "the blue book" (Water Quality Criteria 1972) produced by the U.S. National Academy of Sciences. It includes chapters on criteria for freshwater and marine aquatic life, as compiled by 63 scientists who worked together over about 1.5 years. It is

a good compendium, and I recommend these criteria as a basis for regulations on pipeline construction and related activities in Canada.

The applicability of these U.S. criteria in the Canadian north might be questioned. By and large I do not consider this a problem. The criteria were written with the intention of covering almost all types of water, and would include the types found in the N.W.T. Also, the differences in sensitivities of different species of fish are often not particularly great, a fact that can be documented by examples.

The main factor of special importance in the north would seem to be that the short season for growth and reproduction of aquatic organisms would make them more vulnerable to short-time disruptions. Therefore, it would be more important to adhere strictly to criteria.

WATER QUALITY STANDARDS AND REGULATIONS

Standards are legal limits for amounts or concentrations of pollutants in the water. They must be set down in regulations. They may or may not be based on criteria for any particular purpose, although it is best if they are.

Often the standards are simplified or translated into cut-and-dried tests for ease of regulation or measurement. Sometimes there may be a compromise reflecting social values, conflicting uses, or "best practicable treatment". However nowadays such simplifications are normally carefully thought out to provide final "safe" levels in the environment. For example, current federal regulations on oil refinery effluents (EPS, 1974) set maximum limits for 5 chemical parameters in the effluent, and require that the undiluted effluent should not kill rainbow trout. No-one expects to provide a habitat for trout in the effluent pipe. Rather, the philosophy is that adherence to the simple fish-test will mean that after dilution in the environment, the effluent will have no appreciable sublethal effects on organisms.

IMPLEMENTATION

The following are problems which I have seen in protecting natural waters.

- (1) Lack of specific numerical standards.
- (2) Lack of environmental pre-planning and site lay-out.
- (3) Lack of knowledge of environmentally desirable practice by bosses or individual operators, or failure to adhere to this because of pressures of the primary job.
- (4) Lack of inspection and checking of environmental parameters by regulating officers or agencies, and sometimes simple failure to enforce regulations.

(1) Numerical standards

As mentioned previously, a lack of specific limits on environmental change was obvious in the applicant's submission. The EPB report approaches more closely a suitable code, although some of their recommendations remain general.

In this presentation I put forward the beginnings of standards for some environmental parameters. They may at least serve as a point of departure in reaching more suitable standards.

It is the responsibility of government to lay down the regulations and standards. However the most satisfactory regulations I have seen were developed by joint industry/government task forces (e.g. EPS, 1974). This procedure takes some time, and in the past, government has been slow in getting such agreed regulations into force. In the present case, the machinery would have to work faster, since I understand that if a pipeline is to be built, it should be started soon. The importance of having the regulations available early is self-evident in considering items (2) and (3).

(2) Environmental pre-planning

In the past, environmental protection has tended to be a few patches applied to a work-plan which has already been laid out for efficiency from engineering and economic viewpoints. However, to protect the environment, it must be integrated with the other points of view at the earliest planning stages.

For example, I have seen a small mine spend \$2.5 million over the duration of a 10-year struggle to overcome water pollution, which could have been largely avoided by judicious location

of the mill, tailings pond, and other surface features. As a more relevant example, the engineer's sewer-line down the Guelph trout-stream was an efficient and fail-safe route from the engineering point of view, but was more like a total disaster from the trout's point of view. Environmental patching added on to that route would probably have been ineffective.

The applicant has obviously thought a good deal about routing his operations to avoid environmentally sensitive areas. However, in addition, specific water pollution objectives need to be known early and incorporated into the design-process for each stream-crossing and each operational facility.

(3) Environmental awareness of operators

Again, the specific objectives must be available well before work begins.

The training program for construction people has been well documented by comments of the EPB and government assessment group and I refer to those reports for guidance.

(4) Inspection

The applicant intends to field his own force of environmental people, which I consider commendable, desirable, and effective. However, such a company environmentalist would of course be aware that his salary was paid by the industry which was carrying out the work.

The government will also no doubt, be checking for environmental compliance. However, the speed with which government field officers are allowed to work is notoriously hampered by bureaucratic traditions. Furthermore, it is not without precedent for the zeal of a field officer to be internally dampened.

In short, I subscribe to the EPB point of view on page 53 of volume 1, that a "formal independent body will be required" to carry out the "mechanisms of public scrutiny and accountability". This should be a group of demonstrated capability and integrity.

The independent body should be funded by an overall block grant or contract. The funding should be sufficient to maintain an environmental inspector for each field crew above some minimal number and for each area above some minimal size. The funding must also cover costs of periodic public reporting. I feel that the independent body should play the largest role in the inspection procedure. Furthermore, as one teacher of a large graduating class, I can assure you that a large number of bright young people are searching frantically for such meaningful occupation.

CRITERIA AND REGULATIONS FOR RELEVANT POLLUTANTS

Insecticides

Biting flies are a major factor in any northern operation during the summer-time. Insecticides, the obvious control measure, may have disastrous environmental side-effects. These may be much more serious than the effects of the primary operation, yet they are frequently overlooked or ignored. As a case in point, recent planning of an environmental study of oil-sands development, revealed a huge ongoing fly-control program in the Athabaska river. Its potential damage was great compared to oil-sands operations, yet there did not appear to have been any previous consideration or measurement of the negative impact.

The young stages of blackflies live in running streams, mosquitoes in ponds, and deerflies in watery places. The obvious control method of adding insecticides to the water will unfortunately decimate most kinds of normal aquatic invertebrate communities. One reference by Hatfield (1969) is perhaps sufficient to document this point. If it is desired to protect the aquatic food-chains during pipeline and associated activities, there should be no use whatsoever of water-borne chemicals for biting fly control.

Aerial spraying of insecticides has also been used for control of adult biting-flies. Over two decades of experience with aerial spraying in New Brunswick has shown that it is difficult to avoid side-effects on aquatic invertebrates and fish (Elson, 1975). A long search for a specific insecticide which would hit the target pest but not other organisms has been only partly successful. Even the one now in use, with very careful application procedures, may be showing side-effects on aquatic insects. In my opinion, aerial application of insecticides should not take place in this northern environment with its innumerable bodies of water.

However, I spent a summer employed as a guinea pig to measure the biting rates of subarctic flies, and I realize that comfort of workers is of some overall importance. To achieve this, I think that the maximum use of insecticides should be small-scale local fogging of buildings, and perhaps camps, by non-persistent pesticides. Beyond that, expenditures to alleviate the summer fly problem should concentrate on providing personal protection such as repellents, nylon "insect suits", and similar items.

The applicant has stated that neither insecticides nor herbicides would be used north of 60° north. The criterion and standard in this case is simple.

Regulations should specify:

No use of insecticides or pesticides north of 60°, with possible exception of small-scale ground-based fogging of camps and buildings with non-persistent insecticide.

Siltation

The discussions of siltation damage to aquatic organisms are extensive and adequate in the reports of the applicant, EPB, and government. My only negative comment on these reports is that the early parts of the siltation discussion in section 7.7 of the application emphasizes the very high levels of suspended material necessary to kill fish. The real problem is not that, but the effects of silt settling on the bottom, covered in the later parts of the same section.

The concensus is that pipeline construction would cause some damage through siltation, but that this would be mostly short-term. I agree, but to avoid more serious damage, careful procedures would have to be maintained.

In this situation, everything depends on prevention. Two things are of most concern: (1) day-by-day construction practice and machinery operation; and (2) amount of removal of vegetation cover on land, leading to silt runoff, slumping, and erosion. For each of these things it is difficult to specify the exact procedures which will prevent problems, and it is difficult to maintain a high standard of practice under everyday field conditions. As this is out of my special field, I can only repeat what others have said, that the procedures and practices should be specified in detail in a code of regulations. However, I will say as a non-expert, from what I have seen and read, that I am very pessimistic about the likelihood of success of suggested revegetation procedures.

As an aquatic biologist, I think that there should also be guidelines for amounts of finely-divided solids that are allowable in surface waters as the result of construction activities. Such specified levels would be checks that could be invoked, to protect surface waters which are on the receiving-end of all land-based operations.

However, there are technical difficulties in setting water quality standards for finely-divided solids. Most criteria (e.g. the "blue book") and many background measurements in surface waters are in terms of amounts of suspended solids (the weight of materials suspended in the water). Measuring these requires a careful and time-consuming process of filtration, drying, and accurate weighing. Day-to-day control using this method at numerous points in the field would be cumbersome, slow, and expensive. Furthermore, in streams we are really more concerned about the amounts of solids that settle out on the bottom. In lakes, we may also be concerned about turbidity (light penetration as affected by suspended materials). Both of these are fairly quickly measured under field conditions, but in general we do not have firm criteria relating measurements to the degree of damage to aquatic life.

To further complicate the situation, there are variable relations among measured levels of turbidity, settleable solids, and suspended solids, depending on what kind of material is in the water.

The standards recommended by EPB (vol 4, pp. 224-227) are good, but suffer from this difficulty of application since they are based on suspended solids.

Nonetheless it seems to me that a water-standard is needed, for use as a guideline on whether operations are proceeding satisfactorily. The parameter should be measurable quickly for immediate feed-back. After some consideration, I would recommend that standards be imposed for both turbidity and settleable solids. The former may be measured by an electrically operated turbidimeter, or by comparison with standard formazin suspensions. The latter may be measured by amounts settling to the bottom of a glass cone in an hour. Either standard, or both, could be used in the field.

Before establishing standards, it is desirable to obtain empirical measurements of common relationships for northern waters, among the levels of the three types of measurements of finely-divided solids.

The standards should probably be related on a sliding scale, to the time that the condition persists, i.e. a few minutes or over several days. They should also be related to the increase over the natural condition prevailing at that time, upstream of the man-made disturbance.

As a merely illustrative example, the standard might be something like the following. "Turbidity and settleable solids must not be increased more than 10 times the natural level at any time or place, nor more than 4 times the natural level for an 8-hour period, nor more than twice the natural level for more than 96 hours during any month." A simple graph of levels versus time might be produced. The arbitrariness of the numbers would be lessened if they were related to "blue book" criteria or those discussed in the EPB report.

I would not be able to substantiate suitable numerical values for these regulations without further time for study of the literature. No doubt suitable numbers could be suggested by government scientists participating in writing a code and regulations.

One other regulation should be set up for use when needed. It should restrict the distance downstream in which there are demonstrable effects on communities of stream-bottom organisms. Such a measurement of biological effect is good inasmuch as it is a direct measurement of the subject in which we are interested. It does not require the predictive uncertainties of using the

scientific literature to establish water quality standards, then going from measured chemical or physical parameters back to the predicted effects on aquatic communities. Biological assessment is particularly useful when the water quality criteria are less than certain, as in the case of finely-divided solids. Biological survey is also useful when inspection must be made after the event, since bottom-living organisms reflect conditions for some weeks or months in the past. Biological assessment is in fact, the ultimate test of whether pollution control has been successful.

Biological monitoring also provides a "preventive incentive". No doubt it would give construction personnel a psychological lift, a sense of security so to speak, to know that the aquatic bugs were monitoring around the clock, even if the human inspector happened to be absent because of other duties.

A standard for allowable change in biological communities would of course monitor not only siltation, but all other aspects of water quality as well.

The biological standard might be, for example, something such as "the diversity index of benthic macro-organisms should not be changed more than 25%, at a distance of one-quarter mile downstream of operations."

Regulations should specify:

- (1) Detailed practices for construction, land use, and revegetation;
- (2) Allowable levels of turbidity and settleable solids, related to increase over natural levels at that time, and related to the duration of the elevated levels; and
- (3) Maximum allowable distance downstream for appreciable change in communities of stream-bottom invertebrates.

Petroleum

Oil pollution in northern areas poses special problems because of (a) slow disappearance of the oil, and (b) the vulnerability of many important semi-aquatic birds and mammals. The likelihood of pollution comes not only from oil exploration but from transportation and use, as in any other large construction and operating project.

Accidental spillage should be rare but could be of serious concern. The only way to avoid problems is to prevent them by designing in, ahead of time, adequate safeguards such as encircling dykes, booms, collecting ponds, and easily-available cleanup equipment. These safeguards should be specified in regulations for each class of activity related to the pipeline.

Aside from such spills, there could be damage to waterfowl from continued small leaks or sloppy operations. The damage could be serious if this occurred in staging areas for migration. It has been estimated that as little as 7 grams of oil (1/4 ounce) on the plumage of a duck could lead to its death (NAS/NAE, 1974). The accepted and reasonable criterion to guard against this is "no visible sheen of oil on the surface of the water". This easily-observable and enforceable criterion should also be incorporated in regulations for all oil-related activities in the north.

Direct toxicity of oil to fish and other organisms living in the water would usually be avoided if the above criterion for surface slicks was maintained. However there could be unusual situations where oil was dispersed directly into the water. To protect aquatic life in such cases, regulations should adopt the "blue book" criterion that oil should not exceed 0.05 (= 1/20) of the lethal concentration for aquatic organisms. The resulting numbers could be fairly low. The lethal levels for freshwater fish seem to be in the range of 200 to 2000 mg. of oil added to a litre of water (0.02 to 0.2%), depending on the type of oil (IJC, 1975). Safe levels would accordingly be 10 to 100 mg/l. Lower levels are documented for marine organisms. The most severe toxicity established so far by measuring amounts of oil actually in the water is about 2.7 mg/l which kills lobster larvae in 2 days, and 0.14 mg/l which is the threshold for sublethal effects (Venezuelan crude oil; Wells and Sprague, in press). Other marine crustaceans could be expected to be similarly sensitive.

To summarize, regulations should specify:

- (1) Precise physical safeguards to prevent escape of oil, for each pipeline-related activity;
- (2) No visible sheen of oil on the surface of water; and
- (3) Oil concentrations in water to be lower than 0.05 of the lethal concentration for sensitive aquatic organisms.

Sewage

Lowering of dissolved oxygen is a primary concern from sewage and other organic wastes in the north. This subject is dealt with in excellent fashion by the EPB report (vol. 4, pp. 227-229) and I refer to that as background.

I agree with the EPB recommendation on dissolved oxygen; regulations should specify that oxygen levels should not at any time or place, be depressed beyond the "High level of protection" of the "blue book".

To achieve this would require certain standards of practice for disposal of sewage and other organic wastes, for operations on small or moderate-sized bodies of water. In line with the applicant's proposal, sewage should be stored over winter and lagooned for a year or given equivalent treatment. The stipulation should be added, that except on very large bodies of water, final disposal should be on land, where the material can be assimilated with little damage.

Regulations should specify:

- (1) dissolved oxygen not lower than concentrations for the High level of protection (NAS/NAE, 1974; page 134); and
- (2) sewage lagooned for a year and disposed of on land in most cases.

Temperature

This would not seem to be a major problem. An accident with warm pipe-testing fluid would probably not have long-lasting effects, according to the temperatures stated by the applicant. As a matter of safe practice, such warm water should not be discharged directly to small streams.

Potential damage might more likely be associated with any permanent or semi-permanent operation which discharged appreciable amounts of cooling-water. Such operations; if any, should not be located on small or moderate-sized bodies of water. That could cause disruption of the normal seasonal "clocks" of aquatic organisms, interfering with reproductive and other cycles.

Regulations should specify:

- (1) No discharge of warm water to small waterbodies, with a simple numerical guideline stipulated;
- (2) In permanent or semi-permanent installations discharging warm water, the water-temperature criteria of the "blue book" should be obeyed.

Methanol

One method put forward by Canadian Arctic Gas for disposal of the methanol pipe-testing fluid would yield, after distillation, a residue with methanol concentration of 1% that would be spread on land. Certainly this procedure is satisfactory for aquatic habitats. If, on the other hand, the methanol solution were to be disposed of in water, it should receive immediate dilution to non-toxic concentrations. I would recommend that a fairly modest safety factor of 5 be applied to the known toxicity, for whatever exposure-time is involved.

For estimating this, the toxicity research by the applicant seems reasonable. The lethal concentration of about 2% that they found for fish agrees reasonably with most modern estimates which I have found, e.g. a lethal level of about 1% for creek chub (Gillette et al., 1952). It also agrees with toxicity for some marine organisms, although the brown shrimp is more sensitive, with a lethal concentration of 0.17% (Portmann and Wilson, 1971). Thus it seems that fish would be safely protected for exposures of several days by limiting concentration in the stream to $1/5$ of 1% = 0.2%. This concentration might harm some invertebrates. For fish eggs, the applicant's work seems to indicate a threshold for effect of about 0.1%. Methanol solutions discharged into streams containing eggs, should have concentrations after dilution of $1/5$ this, = 0.02%.

No solution is apparent for the problem of preventing aquatic damage if there is a rupture during testing of the pipe. Any preventative measures that I can visualize, applied at every stream-crossing, might have more overall harmful effects than a rare rupture. I have no solution to suggest, if any is needed.

Regulations should specify:

- (1) Methanol solutions to be reduced to 1% concentration for final disposal on land; and
- (2) If disposal of methanol solutions in water is required, this disposal should be gradual enough that dilution would bring concentration to $1/5$ of the lethal level for fish, or $1/5$ of the toxic level for fish eggs if they are in the river, considering the time-period involved.

Other toxicants

Apparently, no other major pollutants are foreseen. A blanket regulation might be desirable, referring to recommended levels in the "blue Book".

Regulations should specify:

For other toxic or harmful substances reaching surface waters, concentrations should not exceed those recommended in "Water quality criteria 1972".

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laboratory. J. Fish Res. Board Canada 33:

QUALIFICATIONS

In general, qualifications include 23 continuous years of research on water pollution biology, starting with graduate work at the University of Toronto. Following that was 12 years with the Fisheries Research Board of Canada as Scientist-in-charge of pollution studies at the Biological Station, St. Andrews, N.B., then 6 years at the University of Guelph. Most experience has been in the Maritime provinces and Ontario, but a few projects have been in Labrador, N.W.T., and U.S.A.

Most research has been the testing of lethal and sublethal effects of pollutants on marine and freshwater fish and invertebrates in the laboratory. Materials tested have included heavy metals, insecticides and PCB's, crude and bunker oil and oil dispersants, various commercial chemicals, settling solids, low oxygen, high temperature, and high and low pH. Industrial wastes tested have been from mines, oil drilling rigs, oil refineries, and pulp mills. Field studies have been carried out on effects of mine and concentrator wastes, oil refineries, pulp mills, side-effects of aerial insecticide spraying, hydroelectric dams, sewage enrichment, and highway construction.

I have served on several national and international working groups on water pollution. Recommended water quality criteria have been prepared for the Canadian Inland Waters Branch ("Guidelines for Water Quality Objectives and Standards"), the U.S. National Academy of Sciences ("Water Quality Criteria 1972"), and the National Research Council of Canada (criteria for heavy metals).

Standard methods for testing toxicity of pollutants have been prepared for the American Public Health Association and American Society for Testing and Materials. Draft recommendations for incorporating toxicity testing into guidelines and regulations have been provided for the Canada Department of the Environment (pulp mill effluents and oil dispersants) and the Ohio River Valley Water Sanitation Commission.

Service as Canadian delegate on various intergovernmental and United Nations working groups on water pollution has involved meetings in London, Paris, Geneva, Vienna, Rome, Prague, and Jerusalem.

On a consulting basis I have worked on problems of industrial wastes, location of new industries to minimize environmental impact, and planning land use for new developments. Last but not least, teaching of water pollution biology and ecology of resource use to senior fisheries and marine students, and interdisciplinary graduate students, requires keeping reasonably informed on current developments in these fields.

POLLUTION BIOLOGIST/ECOLOGIST

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EDUCATION: University of Toronto
 Ph.D., Zoology 1959
 M.A., Zoology 1954
 University of Western Ontario
 B.Sc., Biology 1953
 with University Gold Medal in Zoology.

EXPERIENCE:

1970-to date University of Guelph, Guelph, Ontario
 ASSOCIATE PROFESSOR, Dept. of Zoology
 ACTING CHAIRMAN, Dept. of Zoology (July-Nov. 1971).

1958-1970 Fisheries Research Board of Canada, St. Andrews, N.B.
 SCIENTIST-IN-CHARGE of Pollution Studies.
 Initiated research program on water pollution
 affecting fisheries in the three Maritime Provinces.
 Research on all kinds of pollution as indicated
 in publication list. Maximum size of group was
 3 scientists, 3 technicians, and summer assistants.

1968-69 Oregon State University, Corvallis, Oregon.
 VISITING ASSOCIATE PROFESSOR while on sabbatical
 leave. Courtesy title, duties limited to seminars
 with graduate and senior classes.

1953-58 University of Toronto
 GRADUATE ASSISTANT. Demonstrator in zoology labs
 for three years when permitted by terms of scholar-
 ships.

1950-52 Governments of Canada and Ontario
 STUDENT ASSISTANT during summers. Worked on biology
 of spruce budworm in Quebec, biology of biting flies
 at Churchill, Manitoba, and surveys of stream bio-
 logy in Southern Ontario.

STUDENT

SUPERVISION: To end of 1975, have supervised 6 M.Sc. and 3 Ph.D.
 candidates; one post-doctorate fellow; and on advisory
 committees of 24 other graduate students at Guelph,
 U.N.B., and McGill.

PUBLICATIONS: Twenty-three research papers in scientific journals and chapters in books, 15 conference papers and circulars, and 18 unpublished reports in technical or manuscript series. Canadian Patent No. 868648 on use of sequestering agents against metal pollution, with Dr. Gordon Brown.

COMMITTEES: Aquatic Environmental Quality Committee, Fisheries Research Board of Canada, 1975-76.

Chairman's Expert Advisory group, Alberta Oil Sands Environmental Research Program, Aquatic Fauna. (Federal-Provincial) 1975-76.

Canadian Technical Committee on Water Quality, International Standards Organization, 1974-76.

Planning Committee, International Conference on Heavy Metals, Toronto, October, 1975.

Member, standing committee on scientific basis for Water Quality Criteria, for Great Lakes region of International Joint Commission, 1974-75.

Chairman, working party on biological effects of pollutants, reporting to ACMR/IABO. (FAO Advisory Comm. on Marine Resources Research/Internat. Assoc. on Biol. Oceanography), 1974-75.

Member, GESAMP (Joint Group of Experts on the Scientific Aspects of Marine Pollution) sponsored by IICO/FAO/UNESCO/WMO/WHO/IAEA/UN, 1973-75.

Member, Committee for Development of Standard Methods for Bioassays, for rewriting section of 14th edition of "Standard Methods for the Analysis of Water and Wastewater". 1973-75.

Member, 1971-72, of freshwater life panel of U.S. National Academy of Sciences Committee on Water Quality Criteria, with task of writing "Water Quality Criteria, 1972".

Member, Aquatic Life Advisory Panel of ORSANCO (Ohio River Valley Sanitation Commission), 1971-.

Member, panel on heavy metals of N.R.C. Associate Committee on Scientific Criteria of Water Quality 1971-72.

Canadian Committee for the International Association on Water Pollution Research, 1968-76. Governing Board of International Association,

1971-74. Technical Program Co-ordinator for the Canadian Committee, 1971-72, Treasurer 1973-74.

Associate Editor of the journal "Water Research" 1971-72.

Member, N.R.C. Associate Committee on Water Pollution Research, 1965-68.

Canadian delegate to Plenary Group on Water Pollution of the Organization for Economic Co-operation and Development (OECD) meeting in Paris, 1961, 62, 63, and 66.

PERSONAL:

Born February 16, 1931, Woodstock, Ontario.
Married, five children. Height, 6'1", weight 185 lbs.
health good. Past president of Kiwanis Club, Home
and School Association, and Swimming Club in
St. Andrews, N.B.

PUBLISHED CHAPTERS IN BOOKS

- Sprague, J.B. 1973. The ABC's of pollutant bioassay using fish.
pp. 6-30 In: Biological Methods for the Assessment of
Water Quality. (J. Cairns and K.L. Dickson, eds.).
ASTM STP 528, American Soc. for Testing and Materials, 526 pp.
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knowledge, dangers, and research needs. pp. 168-189.
In Pimlott, D.H., K.M. Vincent, and C.E. McKnight (Eds.).
Arctic alternatives Canadian Arctic Resources Committee,
Ottawa, Ontario, K1P 5C5, 391 pp.

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- Wells, P.G., and J.B. Sprague. in press. Effects of crude oil
on lobster larvae in the laboratory. J. Fish. Res. Bd.
Canada, 34:
- Sprague, J.B. in press. Current status of sublethal tests of
pollutants on aquatic organisms. J. Fish. Res. Bd.
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- Hodson, P.V. and J.B. Sprague. 1975. Temperature-induced
changes in acute toxicity of zinc to Atlantic salmon
(Salmo salar). J. Fish. Res. Board Canada, 32: 1-10.

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- Sprague, J.B. 1971. Measurement of pollutant toxicity to fish. III. Sublethal effects and "safe" concentrations. *Water Research*, 5: 245-266.
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- Sprague, J.B. and D.W. McLeese. 1968. Different toxic mechanisms in kraft pulp mill effluent for two aquatic animals. *Water Research* 2: 761-765.
- Sprague, J.B. and D.W. McLeese. 1968. Toxicity of kraft pulp mill effluent for larval and adult lobsters, and juvenile salmon. *Water Research* 2: 753-760.
- Sprague, J.B. 1968. Avoidance reactions of rainbow trout to zinc sulphate solutions. *Water Research* 2: 367-372.
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- Saunders, R.L. and J.B. Sprague. 1967. Effects of copper-zinc mining pollution on a spawning migration of Atlantic salmon. *Water Research* 1: 419-432.

- Sprague, J.B., P.F. Elson, and R.L. Saunders. 1965. Sub-lethal copper-zinc pollution in a salmon river - a field and laboratory study. *Internat. J. Air and Water Pollution*, 9: 531-543. (Also published in *Advances in Water Pollution Research*, Proc. Second Internat. Conf. Water Pollut. Res., Tokyo, August 1964, Vol. 1: 61-82, Pergamon Press, London).
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Cooke, N.E. (Chairman), W.S. Cotton, R.M. Dunlop, I. Gruchy, W.A. Mannel, J.B. Sprague, I.L. Stevenson, D.R. Warren, G.S. Wilberg, and J.W. Watkin (Editor). 1973. Lead in the Canadian Environment. National Research of Canada, Environmental Secretariat Pub. No. BY73-7 (ES), NR No. 13682, 116 pp.

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- Sprague, J.B., and William G. Carson. MS, 1970. Spot-checks of mercury residues in some fishes from the Canadian Atlantic coast. Fish. Res. Bd. of Canada, MS Rept. Series, No. 1085, 16 pp.
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